RADIATION DETECTOR

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a novel radiation detector that can be used for detecting in position ionizing radiations such as charged particles, photons, X-rays and neutrons. In the detector according to the invention, the primary electrons resulting from ionization of the gas by radiation are multiplied under the effect of a high local intensity electric gradient field, and collected by the same structure.

2. Description of the Prior Art

Radiation detectors exploiting the process of ionization and charge multiplication in gases have been in use with continued improvements for many years. Methods for obtaining large "stable" proportional gains in gaseous detectors are a continuing subject of investigation in the detectors community.

Among the most widely known of such detectors is the

parallel plate chamber (PPC). PPC has a counter obtained by means of two parallel grids spaced from one another by a few millimeters and between which the electrons are multiplied. This zone located between the two parallel grids is called the "multiplication zone". Thus, the multiplication zone of such a detector is in the form of a single volume defined by the two grids. Due to the fact that it constitutes a single volume of a relatively large size, such a counter suffers from the disadvantage of being very breakdown sensitive. Moreover, the counters of such parallel plate detectors can only have a limited spatial resolution and due to the plate/grid thickness cannot be arranged in such a way as to form detectors having varied shapes. Finally, because the avalanche size depends exponentially on the distance of the primary ionization from the anode, PPC are not proportional counters.

Another type of gas detector is the multiwire proportional chamber (MWPC), which has a plurality of equidistant anode wires held taut in one plane. On either side of said plane are placed two taut grids forming cathodes. Electron multiplication takes place in the vicinity of the wires, because at this location there is a high electric field. However, the MWPC suffers from an

intrinsic limitation: at high radiation rates, the production of slow positive ions results in the build-up of a space charge, which interferes with the counting and reduces gain. In addition, the physical characteristics of the MWPC does not permit the detector to have varied shapes.

A way to overcome on limitations of gain in parallel plate and multiwire proportional chambers (MWPC)is the multistep chamber, thereafter designated as MSC. In MSC chambers, two parallel grid electrodes mounted in the drift region of a conventional gas detector and operated as parallel plate multipliers allow to preamplify drifting electrons and transfer them into the main detection element. Operated with a photosensitive gas mixture, the MSC chamber allows to reach gains large enough for single photodetection in ring-imaging CHERENKOV detectors, thereafter designated as RICH.

A more recent gas detector type is the microstrip gas chamber (MSGC). In the MSGC, the counter consists of coplanar electrodes etched on an insulating support. The major disadvantage of this detector is its relatively low gain limited essentially to 5,000, because it does not permit the superimposing of several counters. In

addition, like the counters of parallel plate detectors described hereinbefore, the counters of these microstrip detectors have anisotropic multiplication zones localized on very thin tracks (approximately 10 micrometers), which makes them very sensitive to discharge damage. These detectors also suffer from the disadvantage of being relatively fragile and susceptible to aging.

Motivated by the problems mentioned above, a large effort has been devoted to find more rugged alternatives to MSGCs. Accordingly, a new class of detector called Micro-Pattern Detectors (MPD) developed.

F. BARTOL and al. Journal of Physics III 6 (1996), 337, introduced a new detector device (MPD) designated compteur à trous (CAT), which substantially consists of a matrix of holes which are drilled through a cathode metallic foil. The insertion of an insulating sheet between cathode and buried anodes allows to guarantee a good gap uniformity and to obtain high gains.

Another radiation detector device (MPD) was introduced at about the same time by Y. GIOMATARIS and al., Nucl. Instrum. And Meth. A376 (1996) 29. This detector thereafter designated as MICROMEGAS is a high gain gas

detector using as multiplying element a narrow gap parallel plate avalanche chamber. In a general point of view, such a detector consists of a gap in the range 50 to 100 micrometer which is realized by stretching a thin metal micromesh electrode parallel to a read-out plane. Very high gain and rate capabilities have been attained due to the special properties of electrode avalanches in very high electric fields. A major inconvenience of this detector lies in the necessity of stretching and maintaining parallel meshes with great accuracy. The presence of strong electrostatic attraction forces adds to the problem, particularly for large size of the detectors. To overcome this drawback, heavy support frames are required and the introduction in the gap of closely spaced insulating lines or pins with the ensuing complication of assembly and loss of efficiency is necessary.

A further, still more recent gas detector type (MPD) is the gas electron multiplier (GEM). This detector consists of a set of holes, typically 50-100 micrometers. in diameter, chemically etched through a metal-kapton-metal thin foil composite, each of which produce a local electric field amplitude enhancement proper to generate in the gas an electron avalanche from each one of the

primary electrons. The GEM acts as an "electrostatic lens", and operates as an amplifier of given gain for the primary electrons. Charge detection is achieved by a separate readout electrode.

Exploiting the polyimide-etching technology developed for making GEM electrodes, other MPD detectors have been developed such as the microgroove (Bellazzini et al., Nucl. Instrum. And Meth. A424 (1998) 444) and the micro-wire (Adeva et al., Nucl. Instrum. And Meth. A435 (1999) 402) detectors.

However, all MPD devices exhibit a fast increasing discharge rate with voltage when exposed to high rates or highly ionizing alpha particles, hence a limitation in gain. In order to overcome this limitation, several devices (notably GEM devices) can be stacked for further gain, but to the expense of mechanical flexibility.

SUMMARY OF THE INVENTION

The present invention is provides a radiation detector of very high performance that overcomes the above-mentioned drawbacks of the radiation detectors of the prior art.

The present invention provides a radiation detector that appears to hold both the simplicity of the MSGC chamber and the high field advantages of the MICROMEGAS, CAT and GEM radiation detectors, however mechanically much simpler to implement, less prone to discharge damage and more versatile in use.

More particularly, in accordance with the present invention, a radiation detector is provided in which primary electrons are released into a gas by ionizing radiations in a drift chamber and then drift to detection electrodes by means of an electric field. The radiation detector of the invention includes three superimposed planes of longitudinal electrodes, arranged in a non parallel geometry when viewed from above (e.g. each of three planes being at a 60 degree angle when compared to the others), so that they form a lattice. Each crossing of the three superimposed longitudinal electrodes provides an intense electric field gradient which acts as a gas electron multiplier (avalanches) for the primary electron produced in the drift chamber. In addition, the three superimposed planes of longitudinal electrodes also act as a read out device collecting the charges created during the avalanche process. Accordingly, the lattice of

longitudinal electrodes acts at the same time as an electron multiplier and as read out device.

The resulting radiation detector allows to detect particles with great sensitivity, and determine their position with great accuracy. It can be used with great benefits in particle physics, but also in medical imaging, gas pressure gauges, materials inspections and many other industrial fields.

The objects, advantages and other particular features of the present invention will become more apparent upon reading of the following non-restrictive description of preferred embodiments thereof which are given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

- Fig. 1 is a schematic view of a radiation detector according to an embodiment of the present invention.
- Fig. 2 is a schematic view from above of the radiation detector according to the invention.

- Fig. 3(a) is a schematic view from above of one of the planes formed by parallel conductive wires, according to an embodiment of the present invention.
- Fig. 3(b) is a schematic view from the side of one of the planes formed by parallel conductive wires, according to an embodiment of the present invention.
- Fig. 4(a) is a schematic view from above of one of the planes formed by parallel conductive wires, according to another embodiment of the present invention.
- Fig. 4(b) is a schematic view from the side of one of the planes formed by parallel conductive wires, according to another embodiment of the present invention.
- Fig. 5 is a flowchart of signal processing for a radiation detector according to the invention.
- Fig. 6(a) to (i) is a step-by-step schematic for the fabrication of a 3- planes dual-purpose physical structure with poliymide spacers.
- Fig. 7 represents a view from above of a radiation detector according to the invention.
- Fig.8(a) to (c) are experimental spectra obtained using a three-planes radiation detector according to the invention using a Fe 55 radiation source.

DESCRIPTION OF THE INVENTION

The present invention provides a radiation detector in which primary electrons are released into a gas by ionizing radiation from a radiation source (10) and are caused to drift to read-out electrodes (1) by means of an electric field (2) generated by applying a negative tension to a drifting electrode (11) located near the radiation source (10), characterized in that it comprises

- a first set of longitudinal electrodes (1) disposed parallel to each other to form a first plane (4) closest to the radiation source (10), said first plane being substantially perpendicular to said electric field (2) and
- a second set of longitudinal electrodes (1) disposed parallel to each other to form a second plane (4′), said second plane being superposed and parallel to said first plane (4) and
- a third set of longitudinal electrodes (1) disposed parallel to each other to form a third plane (4′′), said third plane being superposed and parallel to said first and second planes (4) and (4′),

wherein, when viewed from above, the direction of the longitudinal electrodes (1) in each of said planes forms an angle with the direction of the longitudinal electrodes (1) in each of the other planes, each crossing of the electrodes producing a local electric field gradient, and

wherein the longitudinal electrodes (1) in the respective planes are applied progressively positive tensions relatively to the drifting electrode (11) when going from the plane (4) closest to the drifting electrode to the plane (4'') farthest from the drifting electrode, said plane (4'') farthest from the drifting electrode being applied a positive tension. The electrodes in this plane are intended to collect the electrons.

The gas used in the radiation detector can be any gas or combination of gas susceptible of being ionized and undergo avalanches, such as Helium, Argon, Xenon, Methane, Carbon dioxide, Argon / Carbon Dioxyde combination, etc.

The respective planes of longitudinal electrodes (1) are preferably, but without limitation, separated from each others by 40-60 micrometers.

The use of three planes allows to resolve positional ambiguities in multi-particle bursts, and represents an advantage over two-dimensional detectors.

In a preferred embodiment, the angle between the directions of the longitudinal electrodes (1) in each of said planes is 60 degrees, and the longitudinal electrodes (1) in a given plane cross the longitudinal electrodes (1) in the two other planes at the same points (5) where the longitudinal electrodes (1) in these two other planes cross.

The common crossing point of the electrodes in the three planes ensures a strong electric field gradient at the level of the crossings, allowing more important electron avalanches.

In another embodiment, the longitudinal electrodes forming the planes are conductive strips (6) (metallic or other conductive material).

These conductive strips can be spaced by spacers (7) located at the crossing points (5) of said conductive

strips. Said spacers (7) may be made of glue, polyimide or any other suitable materials.

Mechanical resistance of the detector's physical structure (3) is provided by epoxy, polyimide or any other suitable materials.

These embodiments are made through etching techniques as described in the "experimental procedures" section.

In another embodiment, the longitudinal electrodes disposed forming the planes are conductive wires (8)(metallic or other conductive material).

In a first sub-embodiment, said conductive wires (8) are woven with non-conductive wires (9) to form a mesh, said conductive wires (8) being oriented according to a first axis, and said non-conductive wires (9) being oriented according to a second axis, said second axis being perpendicular to the first axis.

In another sub-embodiment, said conductive wires (8) are individually alternated with non-conductive wires (9) in said first axis. This allows to obtain perfectly parallel and geometrically in-phase conductive wires despite their

passing alternatively above and below the perpendicular non-conductive wires.

The sub-embodiments just described can be made by standard weaving techniques known to the person skilled in the art.

The conductive strips (6) or wires (8) can be made in any conductive materials, such as Tungsten of other metallic or non-metallic conductive materials.

The detector's physical structure (3) according to the invention can be mechanically flexible, depending on the materials used and the size of the device. Accordingly, the detector's physical structure (3) can take various shapes such as cylindrical, semi-spherical or other shapes.

The signal resulting from the individual longitudinal electrodes in each superposed planes is amplified, registered and properly treated in a multi-channel analyzer providing energy and location information for the particles detected by the detector.

EXPERIMENTAL PROCEDURES

Fabrication of a 3- planes detector, poliymide spacers and polyimide support.

STEP 1: Begin with a piece of double-sided copper-clad polyimide (18). Fig. 6(a).

STEP 2: The middle pattern is transferred onto one side of the two-sided copper-clad polyimide piece, using standard photolithography processes. Fig. 6(b).

STEP 3: A piece of one-sided copper-clad polyimide (19) is prepared by completely etching the copper from one side of a two-sided polyimide piece. Fig. 6(c).

STEP 4: The one-sided copper-clad polyimide piece (19) is then glued onto the top of the middle-patterned polyimide piece (18). Fig. 6(d).

STEP 5: The top and bottom patterns are transferred onto both sides of the piece using the standard photolithography processes. Care must be taken to ensure that the cross-over points of the

strips on all three planes are precisely aligned. Fig. 6(e).

STEP 6: The peripheral areas (20) of the detector (on both sides), except in the area active for detection (21), are protected with a thin coating of polymer resin (22) that resists the polyimide etching solution. Fig. 6(f) and 7 (g).

STEP 7: The polyimide of the active area (21) is etched until the glue encapsulating the middle pattern is exposed, and the polymer resin (22) is removed. Poliymide spacers (7) under the copper patterns subsist Fig. 6(h).

STEP 8: The remaining glue in the active area (21) is removed. Fig. 6(i). A view form above of the resulting radiation detector is provided in Fig. 7.

Experimental results with 3-planes metallic strips and polyimide spacers detector

A 3-planes detector with metallic strips and polyimide spacers was successfully implemented according to the

fabrication method above and shown to detect ionizing radiation from a Fe 55 radiation source. For the purpose of the experiment, the individual longitudinal electrodes in each plane were electrically connected. Therefore, the experiment demonstrates the detecting abilities of the detector without positioning function. It would be easy for a person skilled in the art to add the 2-dimensional positioning function by keeping the longitudinal electrodes isolated from each other, registering the signal for each electrode separately, and treating the resulting signal in an appropriate manner (see Fig. 5).

Main characteristics of the detector:

- Radiation source (at the top): Fe 55
- distance of the radiation source to the top plane: 4 millimeters.
- drifting electrode tension : - 2000 V
- top plane tension : - 350 V
- medium plane tension tension: 0 V
- bottom plane tension: + 350 v
- gas: Argon 91%; Carbon dioxide 9%
- gas pressure: atmospheric pressure
- spacers: polyimide

Signal detection:

After proper amplification, the signal detected shows the typical spectrum for Fe 55, with peaks at 3 and 5.9 keV. Fig. 8(a) represents the spectrum detected by the plane (at +350V tension) farthest from the drifting electrode, which collects the electrons. Fig. 8(b) represent the spectrum detected by the middle plane (at ground). Fig 8(c) represent the spectrum detected by the plane closest to the drifting electrode (at -350V tension). The middle plane and the plane closest to the drifting electrode both collect the positive ions.